AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

Topic 1.3 Cell Membranes and Transport – Page 3

I. Osmotic Relationships of Cells

		Completed
1.	Read through Cell Membrane Notes and Complete the tasks a. Define the term **'diffusion'.** Use the term **electrochemical gradient** in your description. b. Across which parts of the membrane do the following molecules / ion diffuse? Explain your answers. • Oxygen • Carbon dioxide • Glucose • Amino acids • Sodium and potassium ions c. Explain how the following affect the rate of diffusion: concentration gradient, temperature, lipid solubility and the size of the molecule d. Distinguish between diffusion and facilitated diffusion e. Explain the terms 'isotonic', 'hypertonic' and 'hypotonic'. f. What is the water potential of pure water and how does this compare to a solution? g. Define the term osmosis using the term water potential in your definition. h. Define the term 'active transport'. i. List the differences and similarities between active transport and facilitated diffusion. j. A cell carrying out active transport would show what features? k. What factors could affect the rate of active transport? l. Draw a diagram illustrating phagocytosis. m. Distinguish between endo and exocytosis. n. With examples explain the difference between phago and pinocytosis.	
2.	Read the BioFactsheet on Water Potential For animal and plant cells explain what happens when they are placed in: Hypertonic Isotonic Hypotonic solutions	
4.	Complete the cell transport quiz.	

Cell Membrane Notes

Whilst cell membranes are only about 7nm wide, they do represent a significant barrier to the movement of ions and molecules, particularly polar (water soluble) molecules such as glucose. This is because such molecules are repelled by the non-polar, hydrophobic lipids of the membranes. It is this lipid bilayer that prevents the aqueous contents of the cell from escaping.

However, transport across membranes has to occur for the following reasons:

- to obtain o______________________ and n______________________
- to excrete w_________________ p____________________
- to maintain a suitable _____ (or _____ concentration) within the cell for enzyme activity.
- to generate _i______ gradients essential for nervous and muscular activity

Why do eukaryotic cells transport more across membranes than prokaryotic cells?

There are **four main mechanisms** by which molecules and ions can be transported across a membrane. They are:

1. **Diffusion** (simple and facilitated diffusion)
2. **Osmosis**
3. **Active transport**
4. **Bulk transport** (endocytosis and exocytosis)

Why are the first two processes classified as passive and the second two as active?

1. Diffusion

This is the movement of molecules or ions in a **liquid or gas** from a region of their **high concentration** to a region of **lower concentration** down their **concentration gradient** until they are **equally distributed**.

Factors affecting diffusion

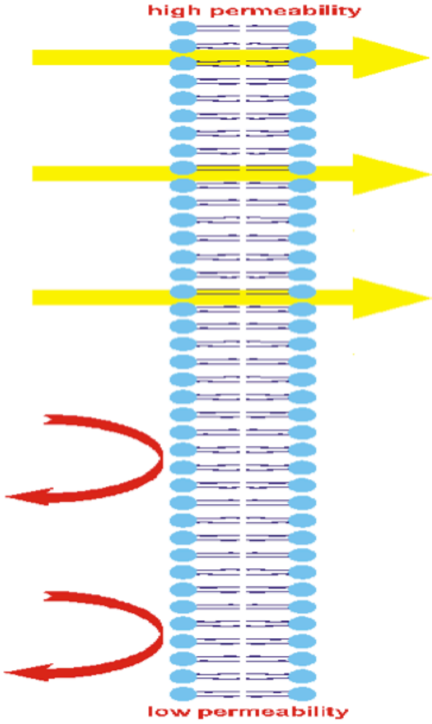
Rate of Diffusion depends on:

$$\text{Diffusion is proportional to: } \frac{\text{Surface area x difference in concentration}}{\text{Length of the diffusion path}}$$

Membrane Structure and Function

Fat soluble molecules can pass through the bi-layer. Charged particles or ions and large molecules such as Glucose cannot pass through the cell membrane because they are relatively insoluble in lipid.

Summarise the permeability to the cell membrane to the following groups of molecules.



<u>Gases (**small non-polar/uncharged/soluble molecules**</u>

<u>**Very small** polar molecules</u>

(NB: water will diffuse slowly)

<u>**Larger**, uncharged molecules</u>

<u>**Charged Ions**</u>

<u>**Charged polar** molecules</u>

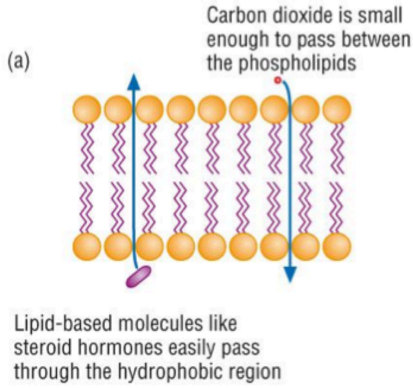
Types of diffusion

As the cell membrane is not equally permeable to all molecules, the cell has mechanisms to allow for the efficient diffusion of molecules to which it is normally impermeable. This type of diffusion is known as **facilitated diffusion**, whereas the movement of substances to which the membrane is readily permeable is known as **simple diffusion**.

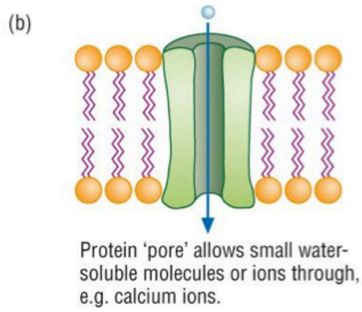
Summarise the differences below.

<u>(a) Simple diffusion</u>

Examples: Steroid hormones



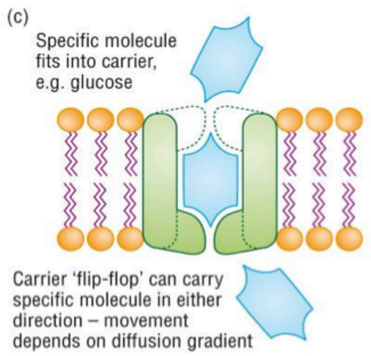
(b) Facilitated diffusion using a **ion channel protein**



Examples: Calcium ions, sodium ions

(c) Facilitated diffusion using a **carrier proteins**

Examples: glucose and amino acids



2. Osmosis

A special kind of diffusion

Although we use the term 'concentration' when we describe the relative amounts of solute in a solution, it is best to avoid using this term in reference to water. Instead, we use the term **water potential**. The process of water diffusion referred to as osmosis also always moves across a selectively permeable membrane.

Therefore, osmosis is the diffusion of water molecules from a region of **higher water potential** to a region of **lower water potential** (down a **water potential gradient**) across a **selectively permeable membrane** until the water is **equally distributed**.

The concept of water potential

Water molecules possess kinetic energy, which means that in liquid or gaseous form they move about rapidly and randomly from one location to another. The water potential of a given system such as the atmosphere, a solution, soil water or a cell is a **measure of the kinetic energy** of the water in the system.

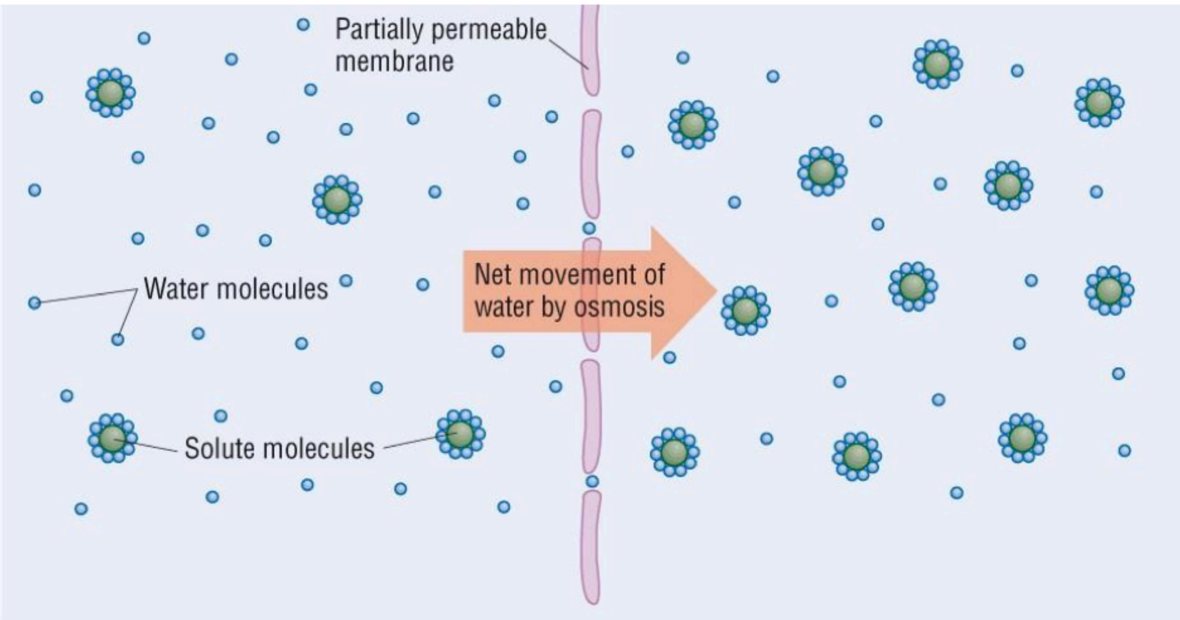
The **greater the concentration of water molecules** in a system, the **greater the total kinetic energy** of water molecules in that system and the **greater the water potential**. Pure water therefore has the highest water potential of any system. By convention, the water potential of pure water is zero and it is measured in **kilopascals (kPa)**.

When two systems containing water are in contact with each other (such as two cells next to each other or a cell next to a solution) the random movements of water molecules will result in the **net movement of water molecules from** the system with the **higher water potential** (higher kinetic energy) **to** the system with the **lower water potential** (lower energy) **until the concentration of water molecules** in both systems **is equal**.

So the water potential is the capacity of a system to lose water and is in effect the diffusion of water molecules.

When solute molecules or ions are dissolved in pure water they attract and hold water molecules to their surface. This reduces the number of water molecules that are free to diffuse out of the solution and therefore **lowers the water potential.**

All solutions therefore have lower water potentials than pure water. The more solute molecules present, the lower (more negative) the value. This means that when water flows down a water potential gradient, the net movement of water molecules is always from a less negative value e.g. -500 kPa to a more negative value e.g. – 800kPa.

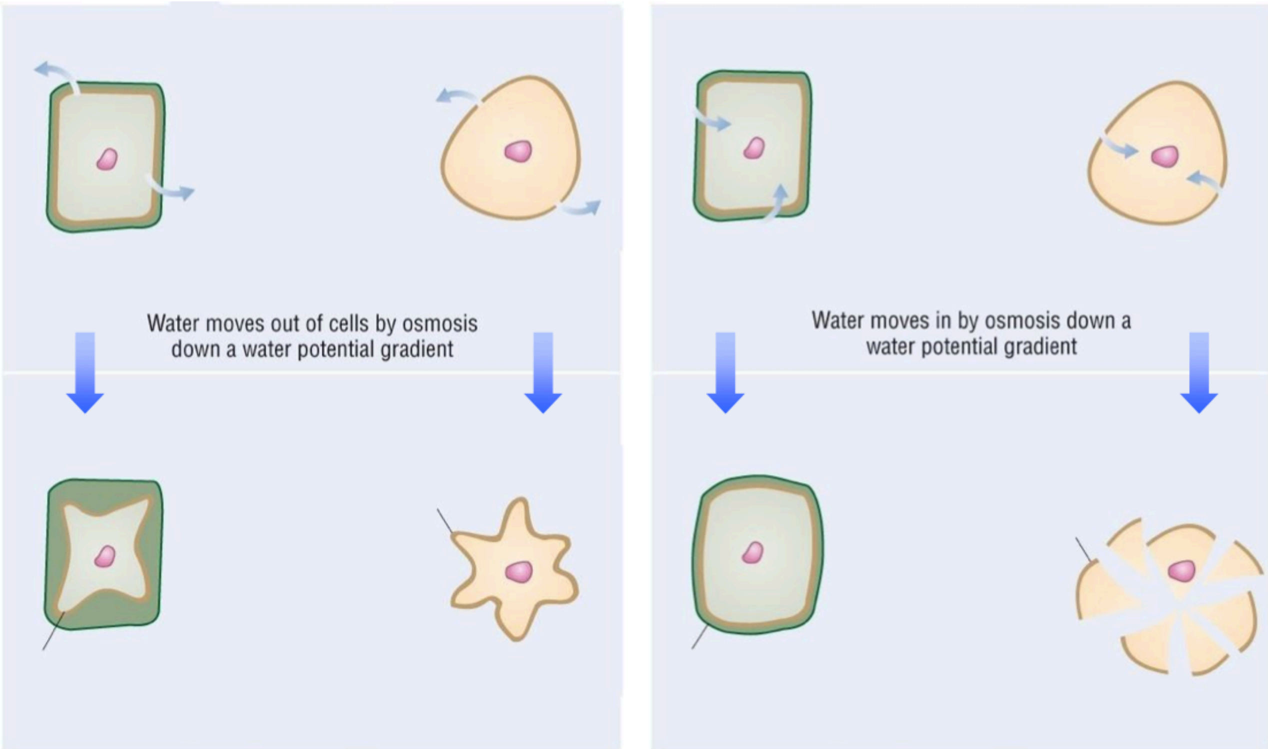


Osmosis, water potential and cells

Why is the water potential of cells always lower than pure water?

Annotate the diagrams below to indicate whether the solution has a higher or lower water potential than the cells, what that means about the solute concentration and the effect on the cells (shown in the lower drawings).

SOLUTION __________ WATER POTENTIAL **SOLUTION __________ WATER POTENTIAL**



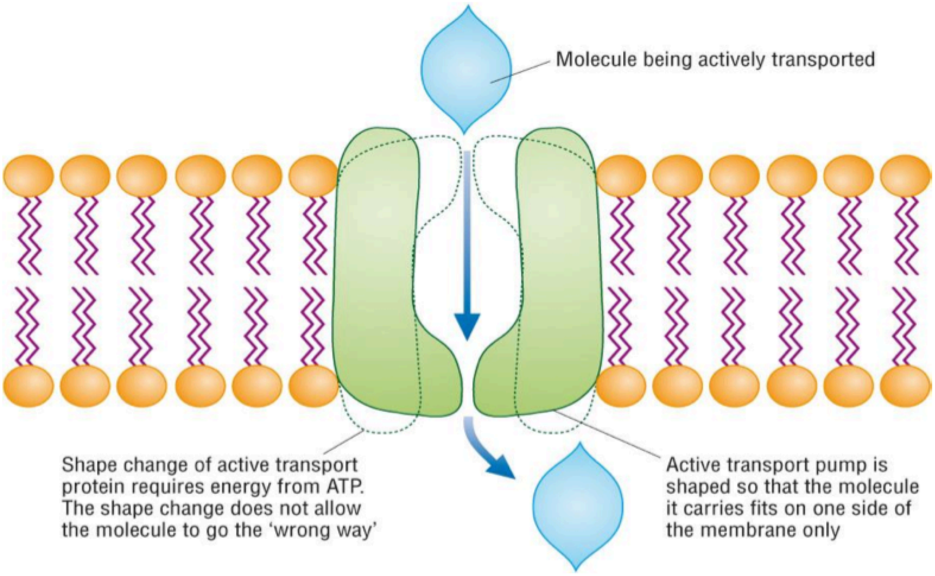
What is the significance of the changes that occur to the plant cells shown above?

Describe an example of osmosis and animal cells

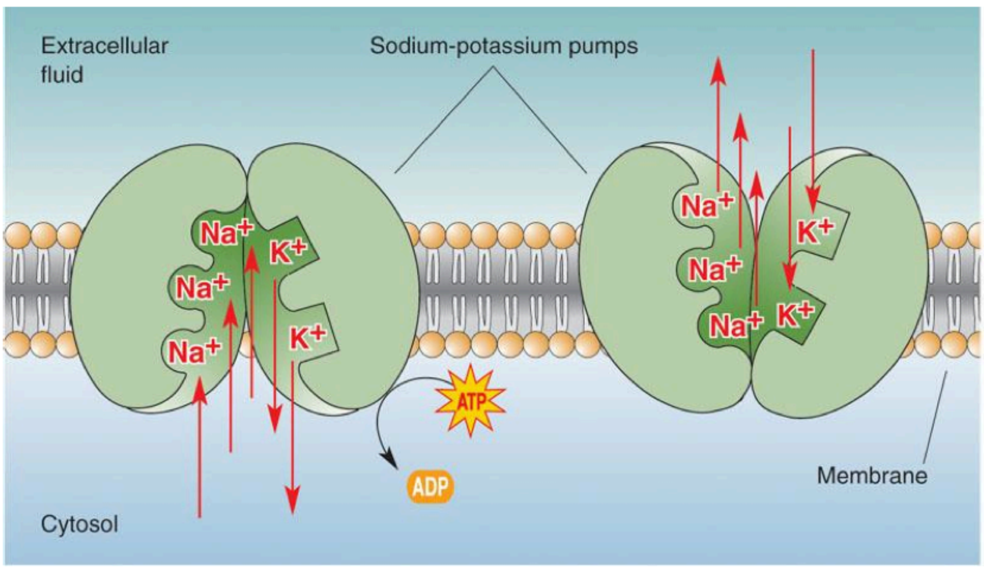
3. Active Transport

This process **uses energy** to move molecules and ions across the cell membranes **against a concentration gradient**. The molecules attach to **specific carrier proteins** (also called 'pumps') in the cell membrane, then molecules of **ATP** (adenosine triphosphate) are broken down to ADP (adenosine diphosphate) and an inorganic phosphate to **release energy**.

This energy changes the shape of the protein, as shown in the diagram below, and moves the molecule or ion across the membrane.



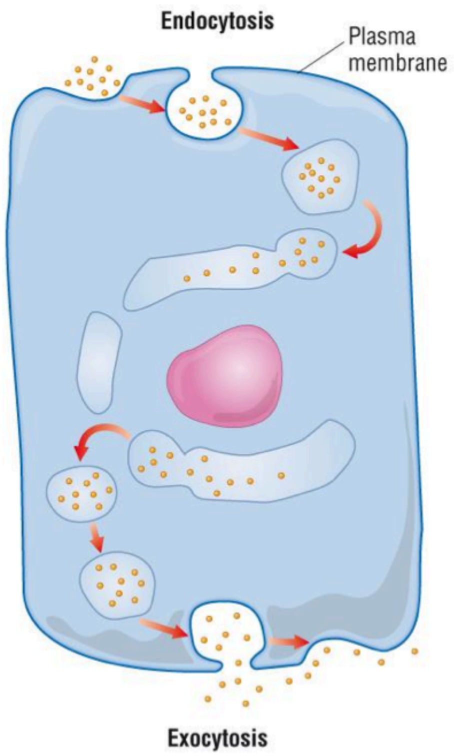
An example of active transport is the **sodium potassium pump** found in animal cell membranes. This pump is essential in controlling the osmotic balance in animal cells – it actively removes sodium ions from the cell. Too many sodium ions inside the cell would cause too much water to enter by osmosis leading to lysis. This pump is also important in many specialised cells such as those that absorb glucose in your small intestine.



4. Bulk transport

This requires the use of energy which is supplied by the breakdown of ATP from respiration. Large quantities of material can be taken into the cell (**endocytosis)** as well as being moved out from a cell **(exocytosis)**.

Endocytosis:



Exocytosis:

Bulk transport can be divided into even more specific terms by the use of prefixes.

Write down the meaning of these prefixes and give examples.

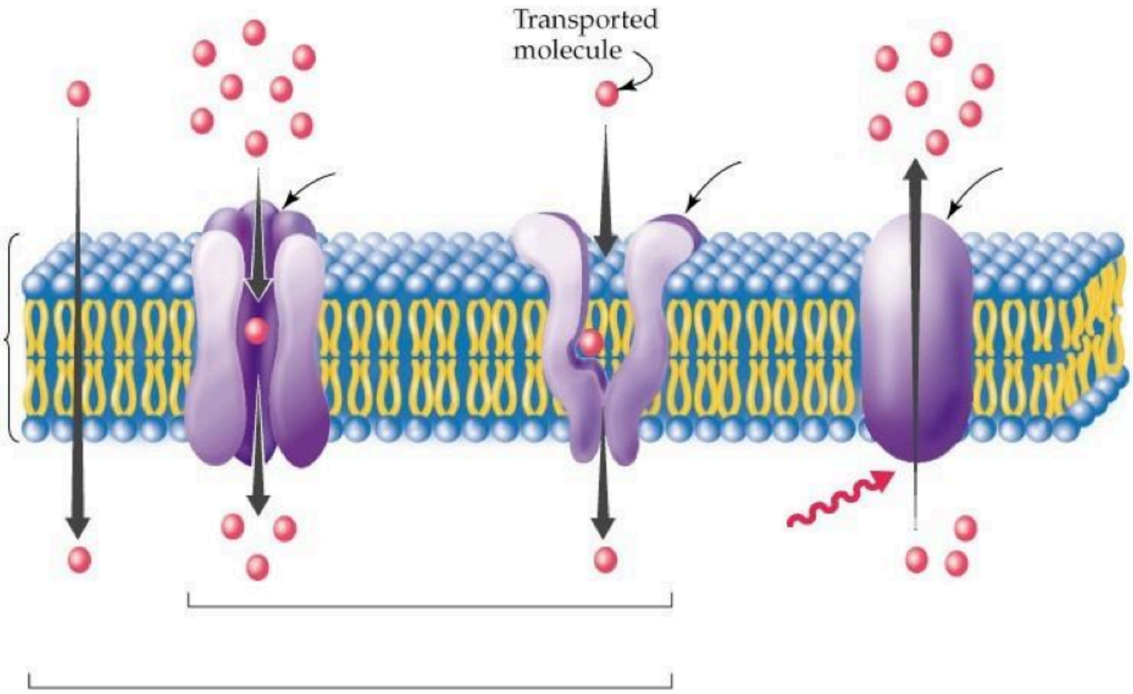
* Endo-

* Exo-

* Phago-

* Pino-

Annotate the diagram below to show the first three types of transport.



Bio Factsheet

Number 54

Water Potential

Water potential strikes fear into many students. However, in reality there are only five typical questions:
1. Here are two cells with different water potentials. Which way will water move?
2. Use water potential theory to explain why water enters and moves across roots.
3. Explain each part of the equation $\Psi = \Psi s + \Psi p$.
4. How can water potential theory be used to explain turgor and plasmolysis?
5. Interpret the water potential graph.

Water potential is defined as **"the tendency of water to enter or leave a cell".** Water moves from a region of high water potential to a region of lower water potential. A crucial point to learn is that the highest water potential is 0. All other water potential values are negative numbers and water moves towards the region with the more negative water potential. Water potential is measured in kilopascals (kPa).

Imagine two cells A and B (In reality, the numbers in the diagram are ridiculous – water potential would never be this low, but they illustrate the point).

A	B
-110kPa	-111kPa

Cell B (-111kPa) is more negative than cell A. Since water always moves to the cell with lower water potential, water would move from cell A to cell B. Usually in exam questions, the numbers are a bit trickier.

A	B
-110.4kPa	-110.5kPa

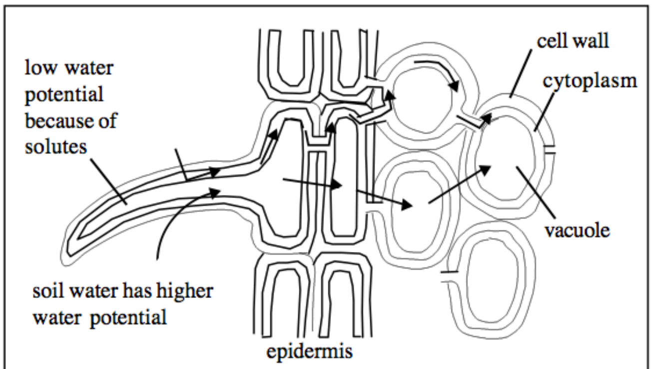
Some students find that the decimal points confuse things. Keep calm - 110.5 is more negative than –110.4 (110.5 is further away from 0) so, again, water would move from cell A to B.

Water potential explains why water enters roots and how water moves across roots.

The movement of water into roots

Roots absorb water through their root hairs. Root hairs consist of a single cell (Fig 1). Root cells contain solutes and this lowers their water potential.

Fig 1. Movement of water into and across the root



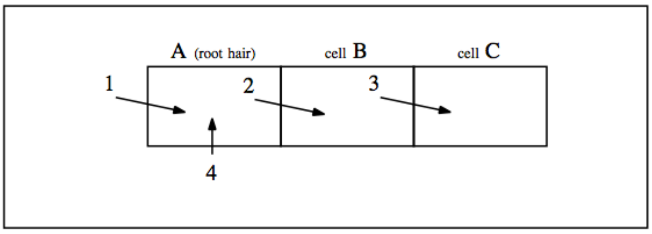
The water in the soil outside the root hair also contains some solutes, but not as many as the cell sap. So the water potential of the sap vacuole (of the root hair) is much lower than the water potential of the soil solution. Since water moves to areas of lower water potential, water moves from the soil solution into the vacuolar sap of the root hair.

Water potential also explains how water moves from cell to cell across the root. Remember that water moves from region of high water potential (soil) to region of low water potential (root hair cell). The water then has to move across the root from cell to cell.

The movement of water across the root

1. Water enters the root hair cell. This increases the water potential of that cell i.e. it becomes less negative (Fig 2).

Fig 2. Movement of water across the root



2. Cell A now has a higher water potential than cell B, so water moves from cell A to cell B
3. When cell B takes this water, its own water potential now increases, so its water potential is higher than C. Now water moves from B to C and so on across the cells of the root.
4. When A loses some water to B, the water potential of A decreases (because the solutes are now in less water and therefore more concentrated), so more water from the soil moves in, etc.

> ***Exam Hint*** *- Many candidates really struggle to explain what is going on in plant cells purely and simply because they are unsure about the structure of a typical cell. Make sure you can draw a plant cell and label the cell wall, cell membrane and vacuole.*

In order for water to enter the vacuole of a plant cell it must cross:
1. the cell wall
2. the cytoplasm
3. the tonoplast (Fig 3.)

When water enters the vacuole the volume of the vacuole increases. This pushes the cytoplasm against the cell wall, which stretches. The pressure of the cell contents pushing against the cell wall is called the **turgor pressure**. In turn, the cell wall is said to be pushing back against the cytoplasm with opposing force. When a cell has taken in as much water as it possibly can and the cell contents are being pushed against the cell wall with maximum force, the cell is said to be **turgid**.

Imagine a cell which is now placed in a solution which has a high concentration of solutes. Since solutes lower water potential the solution will have a low water potential. Water will be drawn out of the plant cell and the vacuole will begin to shrink. Eventually a point will be reached when the protoplast (the living part of the cell) is about to become detached from the cell wall (Fig 4), this point is known as **incipient plasmolysis**. When the protoplast becomes detached the cell is said to be **plasmolysed**

Fig 3. A turgid plant cell

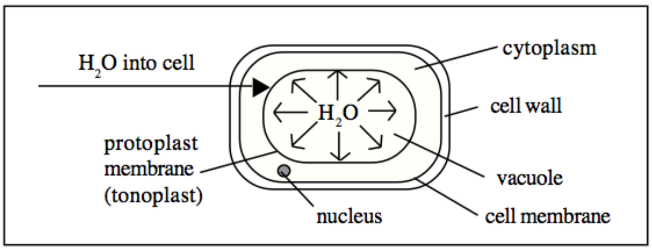


Fig 4. Incipient plasmolysis

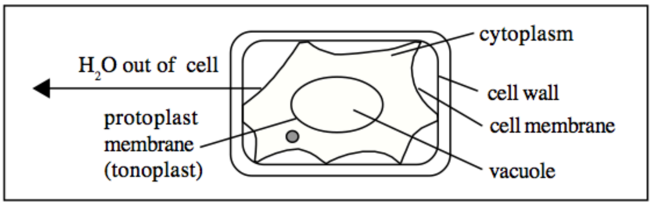
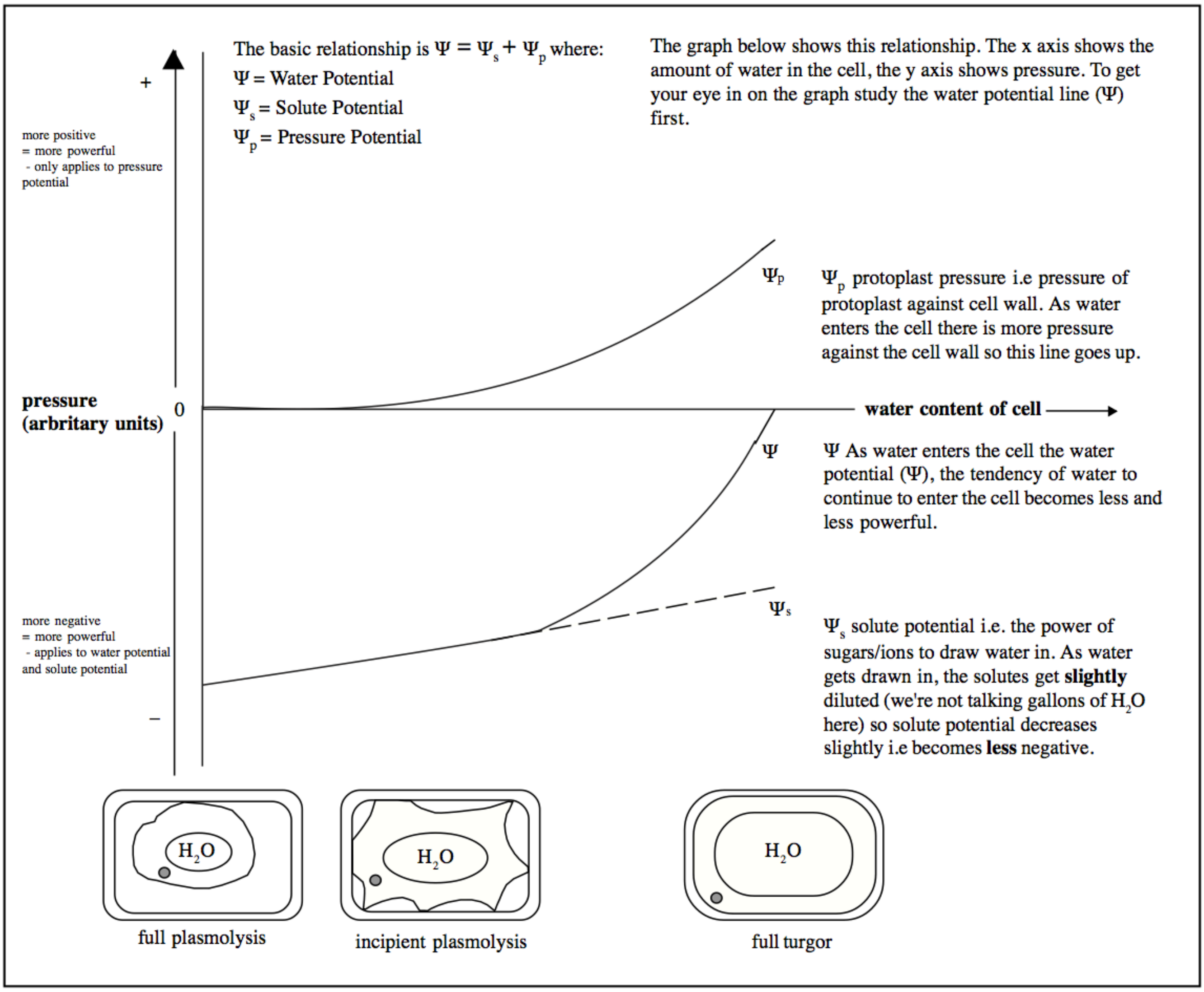


Fig 5. The water potential graph



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(2) PLASMA MEMBRANES AND CELL TRANSPORT (AS)

(The letter before each clue is the first letter of the answer – write the answer in the space below each clue)

A. Kind of transport across membranes which requires the expenditure of energy. (6)

C. Type of protein which moves molecules from one side of a membrane to another. (7)

D. Process describing the net movement of molecules from high to low concentration. (9)

E. Bulk movement of substances into a cell by means of the formation of a vesicle. (11)

E. Way in which substances are removed from a cell within a vesicle which fuses with the plasma membrane. (10)

F. Type of diffusion which requires carrier protein molecules to move molecules across the cell membrane. (11)

F. Name of the "model" used to describe the structure of the cell membrane. (5) (6)

G. Proteins bound to polysaccharides. (13)

H. A molecule which will mix with water but not with fat. (11)

H. A molecule which will mix with fat but not with water. (11)

I. These are a route by which charged particles can pass through cell membranes. (3) (8)

I. Describes two solutions which have the same water potential. (8)

K. Units in which water potential is measured. (11)

M. Theses are used to increase the surface area of a cell to facilitate diffusion. (10)

O. Net movement of water molecules through a partially permeable membrane. (7)

P. Type of transport across membranes which does not require the expenditure of energy. (7)

P. Type of endocytosis which brings solid material into the cell. (12)

P. These molecules make up the cell membrane bilayer. (13)

P. Type of endocytosis which brings fluid into the cell. (11)

P. Describes a cell when water has left it causing the cytoplasm to shrink away from the cell wall. (11)

R. Name of those proteins found in cell membranes which enable hormones and nerve transmitters to bind to specific cells. (9)

T. Describes a cell which is pumped up full of water. (6)

W. A measure of the ability of a solution to absorb water by osmosis. (5) (9)

Z. Water potential of pure water. (4)